NH_3 recovery from digestate using gas-permeable membranes: Effect of wastewater pH

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Agriculture is nowadays the largest source of NH_3 emissions in Europe, with a contribution of a 91% of the total NH_3 emissions in 2016 (EEA, 2018). The harmful effects on the environment and the human health coupled to the current regulation on air quality, which states a reduction commitment for NH_3 annual emissions for each European country, are forcing the development of technologies to mitigate those emissions. Gas-permeable membranes have been proved as an efficient technology to capture NH_3, reducing emissions while recycling nutrients in the form of a valuable ammonium salt. This technology has been successfully applied to recover nitrogen from livestock wastes or anaerobic digestates at laboratory scale (García-González *et al.*, 2015; García-González and Vanotti, 2015; Dube *et al.*, 2016; Riaño *et al.*, 2019). The EU project Ammonia Trapping is aimed at reducing NH_3 emissions in livestock wastes facilities by using gas-permeable membranes. In the frame of this project, this study aims at: 1) recovering NH_3 from anaerobic digestate by a pilot plant, installed at a biogas facility and 2) evaluating the effect of wastewater pH on the NH_3 recovery rate.

The pilot plant was placed inside a mobile container, located next to the digestate storage facility of the biogas plant (Fig. 1). The pilot plant consisted of a NH_3 separation reactor tank of 5.85 m^3 (working volume of 5.10 m^3) that contained 16 membrane modules in vertical configuration. The total membrane surface was 8.85 m^2. The membrane was made of e-PTFE with an outer diameter of 5.2 mm, a wall thickness of 0.64 mm and a density of 0.95 g cm^{-3}. A solution of 1N H_2SO_4 was contained in a 0.25 m^3 NH_3 concentration tank (working volume of 0.15 m^3). This acidic solution was used as a trapping solution and it was continuously recirculated through the membrane. A PLC system controlled the pilot plant. The digestate was mixed in cycles of 20 seconds on and 10 seconds off. The pH in the trapping solution was maintained below 2 by adding concentrated H_2SO_4 whenever the pH of the trapping solution increased up to 2. Aeration in on/off cycles of 180 seconds each was provided to increase the pH in the digestate.

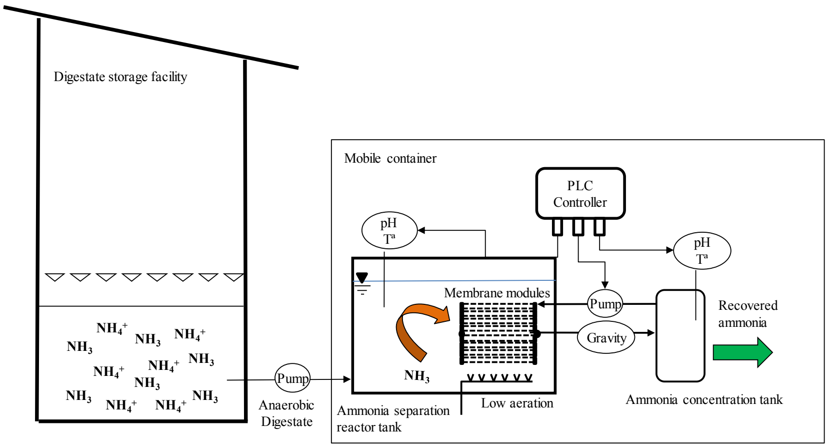

Figure 1. Scheme of the pilot plant.

Increasing pH values were tested, corresponding to pH values of 8.3 ± 0.2 (period I), 8.9 ± 0.3 (period II) and 9.0 ± 0.0 (period III) (Fig. 2a). The study lasted for 26 days and the same digestate was used during the whole study. Initial pH in the digestate was 7.92 and it increased to 8.48 at the end of period I. The same trend was observed for period II, reaching pH values up to 9.3. However, pH was maintained in 9 during period III (Fig. 2a). Thirty seven percent of the initial total ammonia nitrogen (TAN) in the digestate was removed during the whole experimental time (Fig. 2b). As an average, 52% of the removed TAN was recovered in the trapping solution. The trapping solution reached a final TAN concentration of 18.8 g TAN L^{-1}, meaning that TAN was approx. 6 times concentrated than in the digestate. The TAN recovery rate was around 14 g m^{-2} membrane day^{-1}

for the three pH-values tested. TAN removal was greater during period II, with a pH of 8.9 ± 0.3, with a 19% out of 37%.

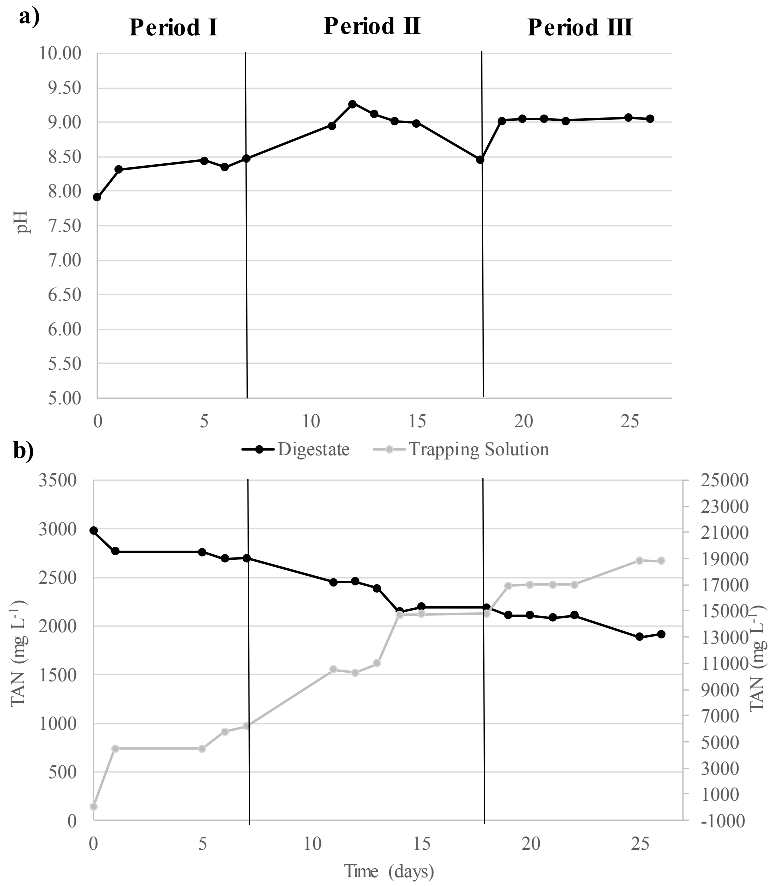

Figure 2. pH in the digestate (a) and TAN removal and recovery (b) during periods I, II and III.

Nitrogen recovery from digestate by gas-permeable membranes was greatly affected by pH in the anaerobic digestate. Although high pH values enhance NH_3 removal, a high proportion of this NH_3 is lost to the atmosphere by stripping. In order to avoid NH_3 stripping, it is recommended to increase the ratio of membrane surface per volume unit of digestate. Besides its contribution to NH_3 emissions reduction, this technology contributes to the recovery of nutrients in the form of a valuable product.

Acknowledgements
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